



# Personal Air Vehicle & VTOL: An Insight

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## General Note

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## ABSTRACT

The rapid progress seen in the areas of Science and Technology have not resolved even some of our basic transportation issues. The challenges only seem to have increased with the passage of time. The ever increasing population coupled with the increasing trends of transportation requirements is pushing the scientists and the R&D engineers across the globe to invent and discover more efficient aircrafts which are not only eco-friendly but also provide a convenient and cost effective means of transportation of man and material. The evolution of Personal Air Vehicles (PAV) is expected to provide a possible solution for this problem. The design of the PAV was evolved from the appearance of a flightless bird named Puffin which is eco-friendly in nature and so, its structure is incorporated in the basic skeleton of the vehicles by few scientists. The striking appearance includes an unusual landing tail sitter which has its landing gear covered while it is in flight mode. The unique features include vertical take-off and landing which is uncommon but can be used effectively under emergency situations. It is firmly believed that the subtle intricacies and robustness of the vehicle would add to the future charisma in the field of Aerospace Technology. The usage of electric powered motors, propeller rotor hubs, and electric actuators for the wing and tail vertical stabilizer flaps are some of the salient features of the vehicle. The project primarily involves three basic aspects namely design, analysis and fabrication of the vehicle. The design includes creation and refinement of the basic part drawing using the "CREO PARAMETRIC 1.0" platform. This platform was been chosen after a detailed study of the various options available and after comparing the merits and demerits of the various packages existing today. It was also decided to use the latest version of the ANSYS package. Accordingly, the version 13 is employed. Other software such as "FOIL Sim" and "DESIGN FOIL R6" version are used for the selection of the type of aero foil required for building the vehicle. The fabrication part of the project is done considering the various international standards, Golden Ratio, etc. Special attention is being given to details regarding aerodynamics and other Flight theories etc. Needless to say, due consideration is given to fabricate the

vehicle that is not only sturdy and robust, but also reliable. This vehicle, once fabricated in full scale and released for commercial purposes in the market is expected to bring a revolution in the Aerospace Technology. Not only its high speed (of about 150mph) with a range longer than that of the helicopter of about 80kms for single charge of the battery but also the attractive features such as the hovering capability of the helicopter, the forward propulsion property of a turbo prop plane etc. would make it viable for high and optimum utilization. It is expected that in the next few years, this vehicle would be put to use in all domestic applications for JIT transportation by both manned and unmanned applications. Military arms and ammunitions can ideally be transported by this vehicle. From the point of view of the manufacturers, it gives a greater ROI (Return on Investment) due to its high and better USPs (Unique Selling Potential). Last but not the least, due to its compliance with the Green Revolution, this vehicle can be freely used and could be considered on par with a bicycle when low emission levels are considered.

**Keywords:** PAV, VTOL

## 1. INTRODUCTION

An air vehicle (aerial vehicle) is that is capable of staying, hovering or moving in air by creating certain thrust. This vehicle when used for one's personal use is called as a "Personal Air Vehicle". A personal air vehicle or PAV, also personal aerial vehicle, is a class of light general aviation aircraft which meets design and performance goals intended to make flying as commonplace as driving. Operations other than scheduled air services and non-scheduled air transport operations for remuneration or hire come under this category. Large range of activities, both commercial and non-commercial, including private flying, flight training, air ambulance, police aviation, aerial firefighting, air charter, bush flying, gliding, skydiving and many others fall under this type. Homebuilt aircraft, light-sport aircraft and very light jets have emerged in the recent years as new trends in general aviation system of the PAVs.

The PAVs have gone from being a novelty to being the work horse of the aviation industry performing tasks of every imaginable description. The industry has seen development of a large commercial fleet which has exceeded the air carrier and corporate aviation fleets in size. Such growth has not occurred by sheer accident but because of the rapid developments of such machines and the ingenuity of the human work force coupled with innovative ideas of design. Towards meeting the ever increasing demand of simple, easy to operate aviation systems, scientists and engineers have spent enormous time, money and effort in focusing towards, better maneuverability and ease of maintenance.

The fundamental premise of this technology is to make a reduction in the skills required to operate an aircraft. The goal is a "highway in the sky" scenario where an individual is able to fly from a point to another with the ease of driving an automobile. The main reason for existence of these PAVs is to have a free access to a free and non-traffic mode of transportation. This leads to avoiding another problem of fuel losses due to the traffic jams in congested areas. Currently the door-to-door average speed of the cars is about 35 mph. In a place like Los Angeles area, this speed is predicted degrade to 22 mph by year 2020. The U.S. Department of Transportation (DOT) states that 6.7 billion US gallons (25,000,000 m<sup>3</sup>) of gasoline are wasted in traffic jams each year. All this can be avoided when a part of traffic is replaced by the use of such air vehicles.

A typical PAV must have the following features as outlined by the scientists at NASA. It must

- Seat 1 to 6 passengers.
- Have 150–200 mph (240–320 km/h) cruising speed.
- Be quiet (less noisy)
- Be comfortable
- Be reliable
- Able to be flown by anyone with a driver's license
- Be as affordable as travel by car or airliner
- Have all-weather capability enabled by synthetic vision systems
- Highly fuel efficient (able to use alternative fuels)
- Have about 75kms or more range.
- Provide "door-to-door" travel capabilities, via vehicle road ability, or small residential airfields or vertiports with only a short walk from the aircraft to the final destination.

## Types of PAVs evolved

Fulfillment of the NASA vision for PAVs is likely to unfold over the next several decades. Several vehicle types exist which strive to meet the PAV definition:



Roadable Aircraft



Light Sport Aircraft



Push pull configuration



Human powered aircraft



Sail plane



VTOL- Harrier Jump Jet



powered glider



### Roadable aircraft

A roadable aircraft is an aircraft that can also travel along the roads. A slightly different concept that is sometimes referred to as a "flying car", is that of an aircraft that would be practical enough for every-day travel, but would not necessarily be driven on the roads.

### Light Sport Aircraft

A light-sport aircraft, also known as LSA, is a small aircraft that is simple to fly and meets certain regulations set by a National aviation authority restricting weight and performance.

### Typical Air Vehicles

An aircraft constructed with a push-pull configuration has a mixture of forward-mounted (tractor) propellers and backward-mounted (pusher) propellers.

### Push-pull configuration aircraft

### Human-powered aircraft

A human-powered aircraft (HPA) is an aircraft belonging to the human-powered vehicles. It is powered by direct human energy and the force of gravity; the thrust provided by the human may be the only source; however, a hang glider that is partially powered by pilot power is a human-powered aircraft where the flight path can be enhanced more than if the hang glider had not been assisted by human power.

### Sailplane

A glider or sailplane is a type of glider aircraft used in the sport of gliding. It has rigid wings and an undercarriage.

### Vertical Take-Off and Landing Aircraft (VTOL)

A vertical take-off and landing (VTOL) aircraft is one that can hover, take off, and land vertically.

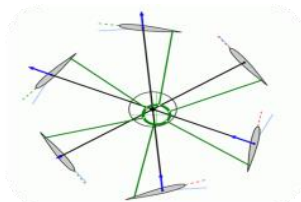
### Powered Para gliders

Popularly known as paramotoring, it is a part of ultralight aviation where the pilot wears a motor on his back (a paramotor) to provide the sufficient thrust to take off using an adapted paraglider or paramotor wing. It can be launched in still air, and on level ground, by the pilot alone — no additional assistance is required. Most vehicles mentioned above cannot yet perform all of the requirements set by NASA. However, a few of these vehicles falling have already established a fair performance across the list of NASA's requirements. In particular, the ultra light aircrafts are of specific interest since their energy consumption is very low. Hybrid forms of the above vehicles would be a great idea to consider. Some of the possible hybrid forms are:

- The Aerovironment SkyTote: This is a combination of airplane and a helicopter. It is also fully automated, similar to driverless cars.
- The Ornithopter is a similar helicopter/ornithopter hybrid.
- The TheoliaWindream One and Hunt Aviation have come up with airship hybrids. Airships may also be foreseen with ground effect modifications.
- The Solar Impulse and the electric airplane feature all-electric propulsion.
- Different parameters make these PAVs distinguished. These parameters can often be combined to generate a new Hybrid model like the ones stated above.



9 Lockheed XFV-1:  
Famous example of  
VTOL



Paddle wheel design in  
cyclogyro



The Bell-Boeing V-22  
Osprey (Concept of  
Tiltrotor)



13 V-22 Osprey hovering



Concept drawing of a  
cyclogyro



V22 in Transition



Lockheed XFV-1  
hovering



Primitive VTOL

#### Typical Air Vehicles

## 2. VERTICAL TAKE-OFF AND LANDING AIRCRAFT (VTOL)

Of all the mentioned types of Personal Aerial Vehicles, the one with a striking appearance and that is suitable to mankind in the present day scenario is the Vertical Take-Off and Landing Aircraft (VTOL). A vertical take-off and landing (VTOL) aircraft is one that can hover, take off and land vertically. This classification includes fixed-wing aircraft as well as helicopters and other aircraft with powered rotors such as cyclogyros/cyclocopters and tiltrotors. The cyclogyro or cyclocopter, is an aircraft design that uses Cycloidal Rotors consisting of airfoils rotating around a horizontal axis for both lift and thrust. They are not only capable of vertical take-off and landing and hovering performance like a helicopter but without the same disadvantages (of balancing problems). A tiltrotor is an aircraft that generates lift and propulsion by way of one or more powered rotors (sometimes called proprotors) mounted on rotating engine pods or nacelles usually at the ends of a fixed wing. It combines the vertical lift capability of a helicopter with the speed and range of a conventional fixed-wing aircraft. For the vertical flight, the rotors are angled so the plane of rotation is horizontal, lifting the way a helicopter rotor does. As the aircraft gains speed, the rotors are progressively tilted forward, with the plane of rotation eventually becoming vertical. In this mode, the wing provides the lift, and the rotor provides thrust as a propeller. Since the rotors can be configured to be more efficient for propulsion (e.g. with root-tip twist), it avoids a helicopter's issues of retreating blade stall, the tiltrotor can achieve higher speeds than helicopters. Some VTOL aircraft can operate in other modes such as CTOL, STOL and V/STOL as well. CTOL is an acronym for conventional take-off and landing, and is a process where the conventional aircraft (such as passenger aircraft) take off and land, involving the use of runways. The aircraft taxi's along the runway until its rotation speed is reached, and then climb into the air. During landings, the aircraft touches the ground while still traveling at a significant forward velocity. The STOL (short takeoff and landing) aircraft has short runway requirements for takeoff and landing and/or STOVL (short take-off and vertical landing). Others, such as some helicopters, can only operate by VTOL, due to the aircraft lacking landing gear that can handle horizontal motion. VTOL is a subset of V/STOL (vertical and/or short take-off and landing). Few standard VTOLs in flight have been shown in the following figures. Besides the ubiquitous helicopter, there are currently two types of VTOL aircraft in military service: craft using a tiltrotor, such as the Bell Boeing V-22 Osprey, and aircraft using directed jet thrust such as the Harrier family. Generally speaking, VTOL aircraft capable of V/STOL use it wherever possible, since it typically significantly increases takeoff weight, range or payload compared to pure VTOL. In addition to the above mentioned modes and types, there are certain unique designs of PAVs that have evolved. The current project "MARMA" is one of its best examples.

## 3. THE REQUIREMENTS OF PAVS AS OUTLINED BY THE NASA

This PAV caters to the needs of the person driving it, as it is fairly simple with use of only limited number of servos to control its various features. It fulfills almost all the requirements of PAVs as outlined by the NASA.

#### Seats 1 to 6 passengers

This PAV though at present, is designed for a single person, sooner or later can be modified, so as to seat more than one at a time. Have 150–200 mph (240–320 km/h) cruising speed. Since, its speed is expected to be about 150mph due to its swept wing structure, it can be considered as a PAV.

#### Less noisy

As there are no balancing problems involved with this vehicle (less number of rotating parts) and the use of electric motors powered by batteries makes it very quiet when compared to other PAVs.

#### Comfort and reliability

It is expected to be very reliable and extremely comfortable as the person who drives the vehicle has a position as if he is sleeping on his belly through the journey.

#### Able to be flown by anyone with a driver's license

As all the controls can be controlled with minimum complexity, it can easily be flown by someone possessing a motor driving license.

#### Cost effectiveness and affordability

Since there are no complex parts or mechanisms and the power system is also very cheap and readily available, the cost of the vehicle is bound to be less. In fact, the cost is less than most of the Luxury Sedans.

#### Highly fuel efficient

As there is no fuel that is used in MARMA, one could expect about 80% efficiency when compared to the 50% achieved when there is usage of IC engines or gas turbines. The battery serves as the sole power for all the actuations and mechanisms involved with this vehicle.

#### Have about 75kms or more range

Since the batteries are highly powered, the vehicle follows a very high range of about 80 kilometers for single battery charge.

#### Provide "door-to-door" travel capabilities

- It is done via vehicle road ability, small residential airfields or vertiports with only a short walk from the aircraft to the final destination. As it requires only a helipad for landing and takeoff, it can practically be placed at the backyard or garage of one's own house.
- From the above described pointers, it can be understood that this vehicle, "MARMA" is "one of its kind" which almost fulfills all the guidelines laid by NASA, for it to be called a PAV.
- When one attempts to design, fabricate and test run an avionic system that is not only cost effective, fuel efficient, maneuverable but also incorporating all the lessons learnt in the past and the challenges faced, it becomes a life-time model that can be converted to reality. Accordingly, sufficient and necessary efforts have been made to consider the various aspects such as ruggedness, user friendliness, ergonomic nature, etc. One of the challenges one would face while venturing to implement such a novel project would be the lack of access to the data or results pertaining to the past experiments and the challenges faced. The project team spent a considerable amount of time, money and effort to reach out to the various material available on the web and also consult subject matter experts (SMEs) who are not only experienced but also are the authorities on the related subjects. It is amazing to see the efforts made in the past with minimal returns and lack of technology but such experiences have certainly helped the team to avoid any serious issues.

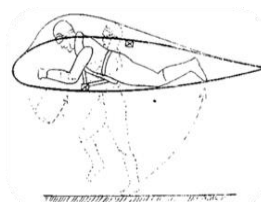
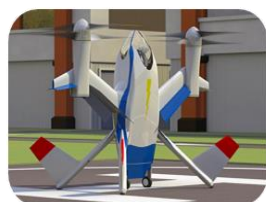
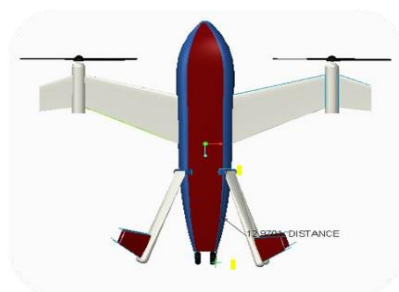
## 4. VTOL PAV- TRIAL

Although there have been consistent upgrading of technology and designs in the field of Aeronautics, there have been even more number of PAVs at different levels of utility and serving different purposes. It has always been challenging to design a vehicle which is efficient and at the same time, light with respect to the weight. So, effective measures have been taken to design and construct a vehicle which meets all the measurement matrices. Needless to say, the measurement matrices are efficiency, weight, fuel consumption, maneuverability and most importantly safety and security. The norms stipulated by the U.S air force form the basis for



such avionic applications and adequate care has been taken to adhere to such norms stipulated. Several avionic specialists like Mark Moore have opined that unless a system goes through all the tests and proves user-friendly for a common man, the innovations are deemed insufficient and ineffective. The process of testing, verification and validation to check if the vehicle conforms to all such stringent conditions is a laborious one and as one could expect, due to paucity of time, such laborious testing has not been attempted during the tenure of this project. Most aviation accidents though some are caused by the pilot error, are due to the flaws in design, construction and testing. So, appropriate attempts are being made to study the concept of physical science supplemented by mechanical and aeronautical aspects of the aviation systems. Accordingly, forensic experts, subject matter specialists, engineers have contributed to the success of not only designing ruggedized aero systems, but also aircrafts which are time tested. Some of the early helicopters used a typical tubular- truss fuselage construction. Although such a construction type had a high strength to weight ratio, manufacturing such an aircraft was quite costly. Each tube had to be cut, fitted and welded in its place. In addition to these disadvantages, it was difficult to stick to exact dimensions with a minimal tolerance. The big advantage of this type of construction is the ease with which it could be repaired in the field, unless there was severe airframe damage which would require jiggling to correct the alignment. Several balancing equipment are available in the market today, several different heads and rotor systems may be balanced with the same basic equipment using a series of adapters and this system not only is used to balance the main rotor, but also the tail rotors, propellers and a variety of other rotating components.

The project, MARMA is an attempt to combine the salient features of all the related aviation systems without compromising on the security and the safety aspects. The word MARMA is taken from Sanskrit, symbolizing the combination of secret and curiosity.



1 VTOL Puffin in flight



PUFFIN Air Vehicles

As the word symbolizes, the personal air vehicle could be rightly used in the areas of defense and security. The curiosity emanates from the fact that several innovative thoughts and ideas have been employed in the design and construction of the vehicle. The conceptual design of MARMA came with the necessity of having a low cost hybrid personal air vehicle. The main reason for this vehicle to come into existence is because of requirement of very less space for parking, i.e., it is less bulky when compared to other PAVs. It can be parked at a corner in the backyard of one's house and requirement of a runway as in Passenger aircraft can be completely eliminated by just having a Helipad for its landing and takeoff.

The design of the vehicle has been thought from that of a flightless bird called 'Puffin'. This bird is highly environment-friendly because the bird hides its own stool, thereby lending a hand in maintaining a good relationship with the environment. This striking feature was employed in the design of the vehicle. Such an eco-friendly system helps in emitting no emissions into the atmosphere. This bird faces the challenge of being incapable to fly due its seating on its hind and its unique and awkward appearance. But an attempt has been made to address this challenge in the project. The requirement to make a flying model the most predominant challenge and this project is an attempt to address such a challenge. This vehicle is one of the very few hybrid PAVs that has the advantages of almost all the existing PAVs. This vehicle comes under the category of a Heli-Plane and so combines the design merits of both

of a helicopter and an aero plane. The limitations of both these vehicles are subdued in MARMA. The balancing problems which are predominant in helicopters are completely eliminated in the yaw direction. This problem is controlled better, even in roll and pitch directions. The highlight of the project being, the requirement of a run-way (as in airplanes) to achieve the cruising speed before it takes off into the air, is completely eliminated. The design features of this vehicle though vaguely resembles a few of the other PAVs, the technicalities remain completely significant and stand out. The vehicle uses a Tilt Rotor system as in V-22 Osprey. But, the design aspects are completely different. While the V-22 osprey takes a vertical take-off; having its body placed at a horizontal position throughout the flight; the vehicle MARMA has a tail sitting upright body that has two propellers attached to the wings of the vehicle. These propellers do not turn a complementary angle as in V-22 model but rather, the complete body makes a transition from the vertical mode to horizontal. The above mentioned differences stand out far from the others, thus making it one of the best and trusted models in the future to come. This vehicle, when it is launched into the market, can be meritoriously used for JIT operations.

## 5. FUTURE SCOPE OF PAV and VTOL

The future scope for any field cannot be forecasted but only be anticipated. The future of personal air vehicles is A is bright and considering the various advantages it possesses over the other traditional concepts, it has a wide range of applications in the years to come. There would be a diversion of traffic to air, which would not only reduce the trafficking problems here, but also would reduce the emissions in the stratosphere region. PAV will set up a revolution in the future generations to come. This will be so, because of the less amount of space, each person will be destined for. In such conditions, this PAV-shall be considered as the sole solution to all the problems. In the following years, there would also be an alt-traffic that is nothing but the regulation of traffic at different heights or levels of atmosphere. This has already been talked about. Within ten years, there are serious developments in this type of air- trafficking of PAVs. This trafficking would be done on top of a multi storied buildings, few of them taller than the others. If one has to fly MARMA at certain height, then he must get into the respective building and fly from the helipad present there. The issue of heights will be based on the experience and the age of the motor driving license of the person. The future may bring a lot of additional features to like the landing skis, in case of water body present in the nearby area, thus, enabling a multi terrain landing possible. As it was already mentioned, since PAV was being used for secret investigations, there could also be a powerful camera that could record the goings on of the enemy. Several other measures can be considered when the future of MARMA is discussed. The above mentioned were quite a few which would definitely bring a revolution in today's world.

## 6. CONCLUSION

The main objective of this project is to research about the various existing models of PAVs and choose a best one that would not only be cost effective, but also would satisfy the needs of zero-emissions and greater fuel efficiency. An ultimate PAV called need to be designed and analyzed deeply. Necessary tests were review is performed starting from the material selection to the type of air foil to be used etc. the fabrication and testing of this vehicle occupies the major portion of this project. The detail aspects of future developments and innovations have also been listed out which not only brings out the scope of the project but also depicts the proximity of the vehicle coming into existence in near future.

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